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Actively decaying or just poorly preserved? Can we tell when plant and invertebrate remains in urban archaeological deposits decayed?

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Abstract

We have recently argued that poorly preserved delicate macrofossil remains of plants and invertebrates in near-surface deposits in York are in active decay, rather than being preserved in stasis, part-way down the decay trajectory. Observations of both archaeological and modern deposits suggest empirically that remains either survive for a long period (if conditions are conducive) or decay rapidly (if they are not). The hypothesis that very gradual decay has led to large numbers of deposits containing remains in a similar state appears illogical. It is more likely that, where poorly preserved biological remains are found, they either decayed in the past and then were stabilised when ground conditions became anoxic, or are currently in decay. Long-term patterns of decay cannot easily be investigated experimentally, but arguments concerning patterns and rates of decay can be. Apart from the question of in-ground preservation, understanding patterns of decay will allow us to address a range of taphonomic problems fundamental to drawing archaeological information from these remains.

Introduction

Biological remains – including organic artefacts – preserved in archaeological deposits by anoxic waterlogging are hugely important as sources of information about the past. It is thus essential to prevent, as far as possible, loss or degradation of this resource. Here we consider easily-decayed plant and animal remains (and obviously artefacts made from such organisms), defined as 'delicate' by Kenward and Hall (2000): material such as plant cell walls and insect cuticles, generally preserved in a largely unchanged state only under conditions of anoxia. Other kinds of preservation, including permineralisation, are a completely different issue.

Our concern here is with urban archaeological deposits (often deeply stratified, as in parts of York and London). Relevant aspects of anoxic preservation have been considered by Caple (nd, see also references therein), although urban occupation deposits appear to have special characteristics rarely found in the mainly rural sites he discusses. In particular, we perceive that anoxia is maintained in many urban deposits by the water-retaining ('sponge') effect of large concentrations of organic matter, holding water above the general water table and making them exceptionally vulnerable to change.

The immediate stimulus leading to the authors' involvement in this line of enquiry was observations of remains from (and the organic matrix of) deposits of medieval date at the Marks and Spencer site, Parliament Street, York (referred to by Oxley nd), where there were biological remains which showed very odd decay, believed to be ascribable to recent changes in ground conditions (Kenward and Hall 2000; Davis et al 2001). In the course of writing about this site we realised that it was probably not very typical of the kind of degradation being undergone by buried organic matter, but we began to suspect that there was a much more general problem: widespread recent decay of organics in the top 1.0–2.0m of York's archaeology. In samples from these deposits rather uniform poor preservation can be seen throughout the 'fossils' and (where present) the organic matrix: in visual terms there is generally some reddening of remains, although the invertebrates sometimes tend to yellow. This in turn led to a broader consideration of the decay of the fossils with which we had dealt on a regular basis for 25 years or more. Our interest centred on how the rate and timing of decay might be determined, factors as crucial to the interpretation of suites of biological remains as to studies of in-ground decay.

In this paper we pose questions relevant to both these areas of study, and attempt to arrive at research methodologies by which they may be addressed in the shorter and longer terms. The questions may be grouped into four related areas: what patterns of decay, within tissues and among species and higher taxa, do assemblages of delicate biological remains acquire under different depositional conditions? In particular (and this is important in arguments about recent decay), can uniform poor preservation come about during the initial process of deposition? What is the relationship between long-term ground conditions and the preservation or decay of the various kinds of delicate biological remains within a given deposit? Given constant conditions, can decay of delicate remains occur extremely slowly (over centuries), or do most of them either decay rapidly or remain in good condition, the transition from good preservation to rapid decay being a catastrophe threshold? Can we determine whether the observed uniform decay of some organic deposits occurred in a past episode, or is a symptom of ongoing degradation?

Placing an academic value on bioarchaeological remains

Before considering these matters, we wish to address a question which we do not think has previously been posed explicitly: how do we measure the potential usefulness to archaeology (and other areas of palaeoscience) of assemblages of delicate biological remains? This is important when judging the seriousness of in-ground decay. We are not concerned here with the questions about relevance to research agendas which are asked during assessment. What matters for the present purpose is: can a degree of degradation be tolerated without significant loss of information which may be considered important in future?

We have attempted to summarise our thoughts in Fig 2.1a. Although, if numerous assemblages are examined, there is a continuum in overall decay states, we suspect that the distribution of quality of assemblage preservation (rather than that of individual fossils) would be found to be neither normal nor unimodal. We have suggested elsewhere that in our experience delicate remains are either well (or fairly well) preserved, or absent, or represented by what appear to be differentially preserved assemblages of the tougher remains (Fig 2.1b; Kenward and Hall 2000).

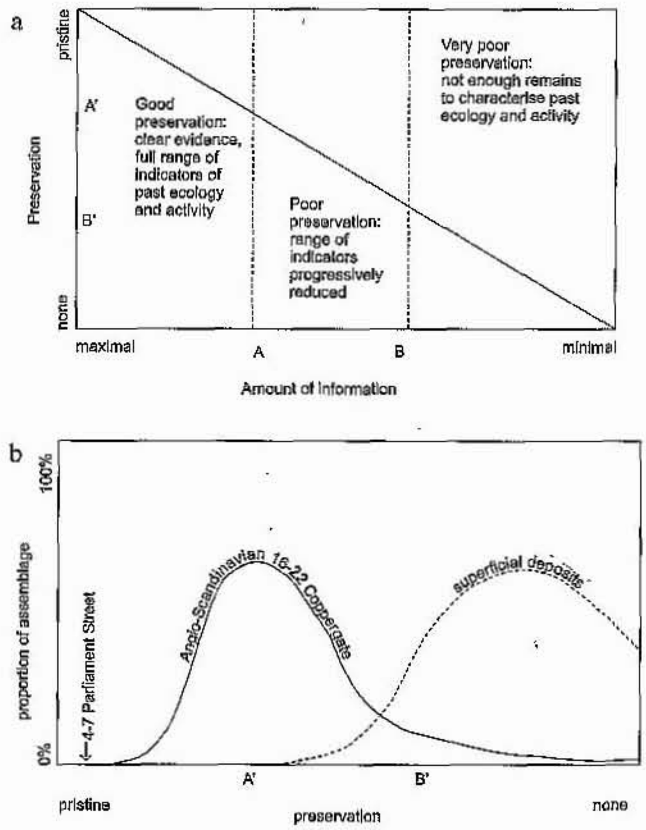

Fig 2.1 a – quality of preservation and information content of assemblages of 'delicate' biological remains in archaeological deposits (scales are arbitrary), note that this diagram does not include information from robust remains such as charred plant remains and bone; b – distribution of overall quality of preservation of 'delicate' plant and invertebrate remains in Anglo-Scandinavian deposits at 16–22 Coppergate, and in superficial deposits generally, in York. Quality of preservation at 4–7 Parliament Street was superior to that in almost all deposits at Coppergate. A' and B' correspond to the intercepts of A and B in Fig 2.1a. These curves are subjective estimates only: early methods of recording preservation and deliberate selection of 'rich' deposits for sampling and analysis mean that there is no overall objective record

With exceptions, these categories correspond to the potential archaeological value of the remains. Good preservation provides clear evidence, with a full range of indicators of past environments, materials and activity. Assemblages with more limited preservation ('poor' in Fig 2.1a) have a reduced potential, and may only provide crude information. A pit fill, for example, may be recognisable as rich in faecal matter by degraded parasite eggs or food remains, but it will not be possible to reconstruct ecological conditions in the pit or its surroundings, or resolve the sources of materials, the full range of foods, or even the species producing the faeces. Where there is very poor preservation there will no longer be enough remains to characterise past ecology or activity at all. We would suggest that in-ground decay is liable to shift assemblages of remains down these categories, and in particular from 'good' (and interpretatively potentially very useful) to 'poor' (and often of limited value). Thus if the information from biological remains is considered at all important, all in-ground decay is to be avoided. (Note, however, that the vertical broken lines in Fig 2.1a cannot strictly be equally positioned for both preservation and information obtainable: the latter will vary with the distinctiveness of what is being interpreted.)

When did decay occur?

We have observed deposits containing delicate remains which showed a substantial degree of rather unusual uniform decay at the Parliament Street site, and showing generally poor preservation in the top metre or so of numerous other sites in York. The former site is probably atypical, and it is primarily with the latter phenomenon that we are concerned here. From an initial assumption that this general degradation had occurred over a long period, because deposits were 'not ideal for preservation', we came round to a very strong suspicion that these layers may be currently in decay as a result of changing groundwater content and loss of anoxia (Kenward and Hall 2000). The problem was that we could not be sure that this decay was recent, and not just a different kind of stable preservation, some way down the decay trajectory. Our arguments concerning this decay require elaboration, and demand a wider consideration of decay of delicate remains. We are concerned with phenomena in medium to high rainfall areas (ie as experienced in north-west Europe), with temperate climates.

Decay of these remains may have occurred during deposition or subsequently, either episodically or very gradually, in the ground. How and when did decay of delicate remains usually happen? Clearly decay will have occurred at different stages in different deposits depending on how the deposit formed, and for different kinds of remains according to their pre-burial history and chemical nature. Over 25 years the authors have examined plant and animal remains in archaeological deposits of all dates (but mostly Roman and later and especially from urban contexts), examining samples from many hundreds of sites, involving analysis at some level of perhaps ten times as many samples. In doing this, we have formed strong (and it must be emphasised, subjective) impressions of the way preservation and decay of delicate biological remains has occurred. We need to stress, shamelessly at this stage of the development of the subject, that we have not carried out experiments to investigate the decay phenomena. The following arguments are thus informed speculation rather than 'hard science'. Our purpose is to arrive at suggestions for practicable investigations which can be carried out on realistic timescales.

The taphonomy of delicate biological remains

The biggest single problem in studying in-ground decay is determining when the observed degradation occurred. We will briefly consider the process of decay from the death of the organism through to the present. Decay can occur: before final deposition; immediately after deposition; in stable deposits subsequent to this; and as a result of changes in deposits. Likely patterns of decay under various preservational regimes are presented in Fig 2.2.

Decay before final deposition

This may have considerable interpretative significance: it may be the result of processing of raw materials (eg fermentation of woad, degradation of comminuted bark in a tanning pit, or passage through mammalian guts) or through decay on surfaces prior to burial (eg in insect 'house fauna' in floor sweepings dumped into pits).

Decay during and immediately after deposition

This will obviously be strongly influenced by the depositional environment (Fig 2.2a and b). It may consist only of fermentation of the more labile components of organisms, for example the food stores of seeds, or muscles of animals. But in many environments there will be fiercer decay which leads to varying degrees of destruction of most plant tissue and non-calcareous animal remains. Following this, decay may be arrested by an aquatic environment, by a moist substratum and the 'sponge' effect, by further deposition, or by other special circumstances which promote anoxia. We suspect that normally the point at which decay ceases depends entirely on the rate at which anoxia is established (there will be exceptions). Remains in anoxic deposits may thus be in pristine condition or be at any stage from this to having completely disappeared. Not only this, but (of course) different remains will decay at different rates, so that quite different suites of organisms may survive to the point where anoxia is established. Which materials decay will depend to an extent on the depositional environment. However, we would argue that decay before, during, and immediately following deposition will typically lead to assemblages of remains showing heterogeneous degrees of decay, and differential preservation. In brief, we would expect a skew towards tougher remains and within any one category of remains, a range of preservation from good (last in) to bad (first in). The importance of this is considered below.

After burial

After burial there may be: effectively no further decay (we beg the question of very long-term processes which belong in the

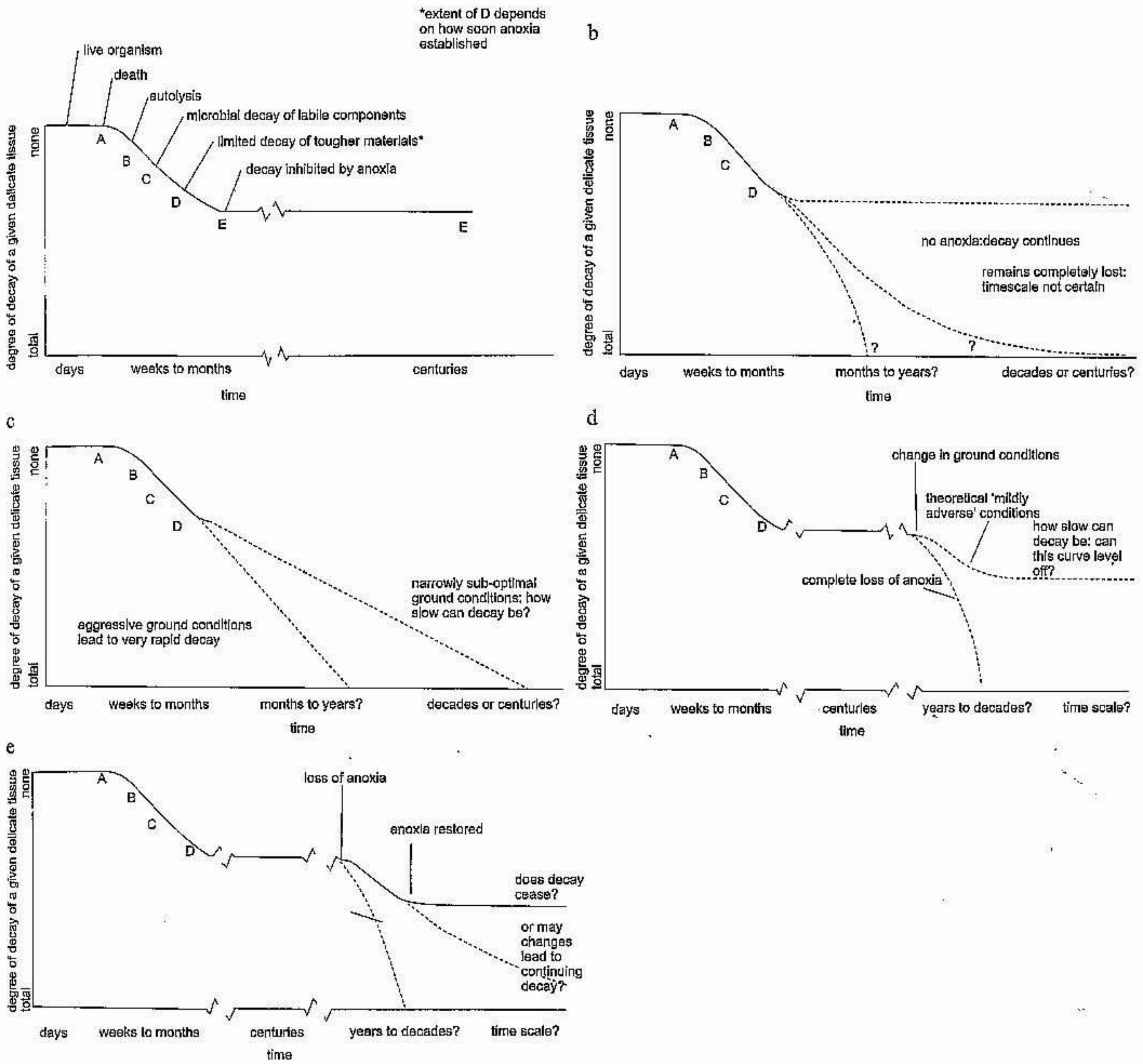

Fig 2.2 Decay of delicate biological remains: a – stages of decay of a given tissue (eg wood or insect cuticle) prior to anoxic preservation; b – decay of delicate tissue where anoxia is not established; c – decay of delicate tissue under aggressive and theoretical 'suboptimal' ground conditions; d – effect of loss of anoxia on delicate tissues; e – what happens to delicate remains when anoxia is restored following an adverse episode?

realm of geology); slow to very rapid degradation leading to loss of most remains on the scale of a year to a few decades; or theoretically (but to us improbably) very slow decay right up to the present and beyond (Fig 2.2c). If the deposit is close to an unstable water table there may be a longer or shorter annual (or occasional) season of decay as the water table falls.

Recent dewatering versus slow decay

The question of how slow decay can normally be, whether it is 'gradual' or incremental (annual or even more intermittent), is crucial in judging when badly preserved remains underwent decay. We think that in general, and under stable conditions, delicate remains are either preserved more or less indefinitely or decay rather rapidly. We thus think that the uniformly poorly preserved remains in superficial deposits are currently in decay as a result of recent dewatering or other changes in ground conditions, and may not last much longer unless conditions are restored (and perhaps not even then?).

The outcome of dewatering of deposits with anoxic preservation will in general terms be the same as that of sub-optimal preservational conditions from initial deposition: fossils will decay and eventually disappear (Fig 2.2d). Complete dewatering will generally lead to complete decay: it will mirror rapid post-burial decay.

The effect of seasonal dewatering of formerly waterlogged deposits caused by development (or climatic change) will resemble that of incremental seasonal decay and the same problem of determining the slowest likely rate of decay exists. Even if this kind of seasonal decay is rapid (eg most fossils destroyed in decades), it will leave us with observable part decayed fossils if the onset was fairly recent. We argued in our recent paper in *Antiquity* (Kenward and Hall 2000) that part decayed fossils in near-surface deposits in York probably fell in this category – we still think that this is the most sensible working hypothesis in the absence of experimental evidence.

Can we determine objectively whether decay is ancient or modern?

How might we distinguish the result of decay during deposition, incremental seasonal decay (providing it can lead to long-term survival of at least some delicate remains), and recent-onset decay caused by changing ground conditions? We cannot answer this question objectively and doubt whether anyone else can at present, but we can at least offer some thoughts on the matter. One obvious line of approach is long-term monitoring (providing that a reliable objective scheme for recording the preservational condition of fossils is established): over a decade or so we might see appreciable further degradation. It is essential that such monitoring is established in many places as soon as possible. However, there may be other approaches which can be adopted in the meantime, and tested in the shorter term. One such approach is to consider likely patterns of decay which might have occurred: during initial deposition and the first burst of post-burial decay; and, recently in dewatered sediments which were formerly anoxic.

Decay during deposition

During deposition, many different species of fungi and bacteria (and some higher organisms) will be attacking different materials at different rates. This will lead to the typically heterogeneous preservation seen in most anoxic deposits – only extremely rarely in our experience are conditions such that pretty much everything seems to survive in excellent condition (eg Littlewoods Store, 4–7 Parliament Street, York, Hall and Kenward 2000, with green leek leaf tissue and insects in superb preservation). A further source of heterogeneity of decay is the different histories of the remains: some may have been processed before burial and others may have lain on the surface for a long period (in each case leading to decay, perhaps characteristic), and others may have been sealed very soon after death (and so be very well preserved). Remains which have lain in a biologically active 'compost heap' environment during the burial process may show patchy preservation across individual fossils as a result of localised biological attack. This is the kind of pattern of decay generally to be observed in 'well preserved' assemblages of delicate biological remains, for example, from many contexts at 16–22 Coppergate, or in the Skeldergate well (Kenward and Hall 1995; Hall et al 1980).

What will in-ground decay look like?

We think this logically predictable pattern of decay is important, for the decay which occurs as a result of changing ground conditions is likely to occur in a very different way. We would argue that the range of organisms present deep in the ground will be limited and that decay will result from the overall conditions of the sediment rather than the varied and lively ecological mêlée of the fresh deposit. We suggest that this will lead to broadly uniform decay, effectively by chemical oxidation whether or not driven by micro-organisms, of all delicate remains and of the amorphous organic material in the matrix. Individual remains and the matrix may show zonal decay as a result of enhanced decomposition along the cracks which form in sediment as it loses water. This is exactly the kind of decay that can be seen in many relatively shallow archaeological deposits and we believe that where it is observed we should work on the strong presumption that recent decay has taken place; this leads to a conclusion horribly relevant to *in situ* preservation: large areas of York's archaeology may be rapidly losing the organic preservation which makes the city internationally important in studying the human past.

How may these phenomena be investigated?

Patterns of decay: can uniform poor preservation arise during initial deposition?

It is essential that we obtain information about how different kinds of remains decay under various depositional regimes (and as a result of different craft, industrial, domestic and natural processes): this includes patterns among tissues and among species. Do assemblages normally show an internal range of decay according to the history of individual remains and the small-scale variations inevitable in most forming deposits?

This can be approached as a piece of experimental science by setting up numerous replicates with a wide range of remains in different sedimentation regimes (mimicking pond silts, house floors, pit fills, etc). (The experimental earthworks projects have done this for one kind of burial environment, but unfortunately they are relevant to contexts with challenging ground conditions rather than the anoxic ones in which we are interested here.) This will be time-consuming and probably require long-term experiments, but would allow experimental control, measurement of sediment parameters, and investigation of the microbiology and biochemistry of the phenomena. However, the same questions can be attacked empirically using observations of suites of remains from modern sediments. Casual observations of the condition of such remains during research into the relationship between death assemblages and local ecology (eg the studies reported by Kenward 1978, and numerous others, unpublished) suggest that for insect remains, at least, heterogeneity of preservation is normal, not least because deposits cover a timespan during which the earliest remains to arrive have had the opportunity to decay before burial. What pattern of decay is normal in active soils, in peats, in anoxic and oxygenated ditch fills, or in piles of decaying vegetation?

This may be the most productive area of research in the short term, and is amenable to work on the timescale funded by research councils, or even in undergraduate projects. The results will also be important in attempts to investigate the pathways followed by delicate remains to archaeological deposits (for example, in a cesspit in which plant remains and 'house fauna' insects from floor sweepings, showing a heterogeneous pattern of decay, are mixed with food plants from faeces and insects which would have lived in the pit, showing excellent preservation).

The relationship between long-term ground conditions and state of preservation

It is almost impossible to establish objectively the relationship between stable long-term ground conditions and the preservational condition of remains, because measuring current sediment characteristics does not tell us what was happening in the sediment in the past. It may sometimes be reasonable to assume steady conditions have existed, for example in deep deposits where there is no obvious mechanism for changing groundwater status. (Even then, changes in rainwater chemistry may have had an effect.) Studies of sediment and fossil micromorphology may give hints that conditions have been stable or have changed substantially. Very long-term experiments in which sediment conditions are monitored in parallel with examination of fossils may begin to build up a body of relevant evidence, but the timescale will need to be multi-decadal.

Can delicate remains decay extremely slowly?

We have argued elsewhere that very slow decay is not likely to be normal (Kenward and Hall 2000), although it may occur under exceptional conditions. We see no reason to alter our opinion, unless experimental work shows otherwise (although it is hard to see how rates of decay so slow as to allow remains to survive for centuries could in practice be measured, or how they could be deduced *post hoc* by examining fossils and sediments).

Can we distinguish past and ongoing uniform decay?

If current ground conditions are good (ie clearly permanently, and not just seasonally, anoxic), then it is reasonable to suppose that where general decay is observed across the biota, then that decay occurred in the past, either during deposition or in some adverse episode. However, we do not know objectively what ground conditions are required to maintain excellent preservation of the full range of remains seen in the 'best' deposits (eg at the Littlewoods Store site, 4–7 Pavement, York, Hall and Kenward 2000). So poor preservation may be the result of current decay even where deposits *appear* suitable for preservation, yet in fact are in some way hostile.

Much research is needed here. It can include an empirical component, characterising in an objective way those deposits where preservation is still excellent, and where it is less good. But in-ground studies and laboratory work on rates of decay of different materials under controlled conditions are essential: we need to relate decay to the biochemical environment. The timescale for such investigations of gradual phenomena may be a problem, but some results should be obtainable over the periods of study appropriate to doctorate research.

There are thus practical approaches to the related problems of the taphonomy of delicate remains and of in-ground decay which can be carried out with modest means. However, the large-scale long-term investigation of *in situ* deposits remains an inescapable priority if we really believe the information locked up in these deposits with anoxic preservation is worth preserving for future research, or even just as a non-renewable component of our archaeological heritage.

Does decay stop when deposits are re-watered?

There appears to be a general assumption that even if it is established that organic remains in particular archaeological deposits are in active decay, the process can be halted by raising the water table and re-establishing anoxia (Fig 2.2e). This may be true, but an argument can be made that in some cases deposits will have been modified by the decay episode in a way which makes them more vulnerable to further damage. It is possible that the loss of organic matter will have two effects: the dense texture typical of richly organic deposits may be lost, and the reduction in organic content may decrease the buffering effect that it has against oxidation (Table 2.1). Aspects of groundwater microbiology and chemistry are emphasised, respectively, by Caple (nd) and Pollard (nd). We wonder whether the decay which follows loss of anoxia is in fact primarily a chemical process, or whether aerobic organisms develop significant populations at an early stage – or even whether anaerobic microbes become

Table 2.1 Likely permanent changes in sediments resulting from temporary dewatering

Deposit has remained anoxic	After decay episode
Dense texture impedes pore water movement	More open-textured
Abundant buffering by organic matter	May be little buffering
Colloidal fine matrix	Fine particles have flocculated and colloidal structure may not re-establish

active as oxygen combines with toxic substances which formerly inhibited them (so that monitoring may not reveal oxygenation). All of this is eminently testable in the laboratory as well as by field observations. Blocks of sediment can be allowed to decay, and then thin sections compared with sections of the undecayed deposit.

If short decay episodes can reduce the resistance of organics to further decay, then re-wetting is only a limited solution to the problem and the case for detailed excavation of representative 'damaged' deposits before further decay occurs is greatly strengthened.

Conclusion

We will round up by re-stating the obvious: decay is a one-way process and therefore once decay has occurred remains cannot be restored, only ground conditions. We feel that this point is sometimes overlooked, leading to a blasé view of the degrading organic archaeological resource. Secondly, we would argue that monitoring ground conditions, although essential, at best only tells us whether decay may or may not be continuing: but we would also argue that there is barely any understanding of the relationship between ground conditions and the preservation of the full range of biological remains. So two lines of research are needed: firstly into the general issue of how delicate remains decay, and secondly into the relationship between easily measured deposit parameters and the rate of decay of delicate remains. Both are practicable, and without both we will not move much further forward, or be able to argue the case for measures to conserve the resource. Until we understand both of these much better it would be wise to work on the assumption of the worst case, that the resource is actively decaying, with all that is implied. The alternative is inaction, which may lead to the loss of a large proportion of the organic matter in anoxic archaeological deposits, and thus of a unique store of information about the past.

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